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Sleep-related attentional bias for faces depicting tiredness in insomnia: evidence from an eye-tracking study

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Abstract

Study objectives: To date, evidence of an attentional bias in insomnia has mostly been obtained through reaction time tasks, with a limited number of studies using eye-tracking. Here, using an eye-tracking paradigm, this study sought to determine whether individuals with insomnia display an attentional bias for novel faces depicting tiredness. *Methods:* Individuals with Insomnia Disorder (n=20) and normal-sleepers (n=20) viewed a series of face pairs depicting neutral and tired expressions each for periods of 4000msec. Eye movements were recorded using eye-tracking, and first fixation onset, first fixation duration, total fixation duration, and total gaze duration were examined for three interest regions (eyes, nose, mouth). *Results:* Significant group x face interactions for total fixation duration and total gaze duration indicated that, regardless of interest-region, participants with insomnia spent more time fixating on and observing tired faces relative to neutral faces when compared with normal-sleepers. Additionally, significant group x face x interest-region interactions for total fixation duration and total gaze duration indicated that participants with insomnia spent more time observing the eye-region of the tired faces than the eye-region of the neutral faces when compared with normal-sleepers. *Conclusions:* Individuals with insomnia display an attentional bias towards tired faces, more specifically for the eye-region compared to normal sleepers. These findings contribute to our understanding of face-perception in insomnia and provide more objective support for cognitive models of insomnia, suggesting that individuals with insomnia selectively attend to faces for tiredness cues.

Brief Summary

Current Knowledge/Study Rationale: Experimental research has yielded mixed evidence concerning the presence and nature of a sleep-related attentional bias in insomnia, and this is the first study to use sleep-specific faces depicting tiredness in conjunction with eye-tracking to objectively examine the presence of an attentional bias in insomnia.

Study Impact: The results from this study provide novel evidence using an eye-tracking paradigm that individuals with insomnia show an attentional bias for sleep-related faces depicting a tired facial expression. It is theorized that people with insomnia attend to and monitor faces for facial cues of tiredness to confirm the physical presence of a sleep deficit.

Abbreviations

ANOVA – Analysis of Variance

DSM-5 – Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.

HADS – Hospital Anxiety and Depression Scale

ISI – Insomnia Severity Index

MSEC – Milliseconds

SSS – Stanford Sleepiness Scale

Introduction

Cognitive models of insomnia highlight the role of attentional biases towards sleep-related cues as a maintaining factor of the disorder, which specifically serve to perpetuate cognitive arousal, distress, and negative thoughts concerning sleep.^{1,2} Despite the prominence of these theories, a limited number of attentional bias studies in the context of insomnia have been conducted. The majority of these studies assessed the presence of an attentional bias by means of reaction time using the dot-probe, the flicker, the Posner, or the emotional Stroop task.³⁻⁹ Whilst influential in confirming the presence of an attentional bias for sleep-related stimuli in insomnia, reaction time tasks are limited to an indirect measure of attention, which approximate gaze location prior to a target response.¹⁰

In an effort to advance the sleep-related attentional bias literature, recent studies have examined the gaze behavior of individuals with insomnia whilst observing sleep-related words and images.¹¹⁻¹³ Individuals generally direct their eye-gaze towards stimuli that attracts their attention.¹⁴ Consequently, by examining where individuals with insomnia direct and fixate their gaze using eye-tracking, a more objective and direct assessment of attention can be obtained.^{15,16} Indeed, eye-tracking allows for visual attention to be continually recorded through the duration of stimulus presentation, expanding upon 'snapshots' provided by reaction time measures.¹⁶ With that in mind, Woods and colleagues¹¹ examined the gaze behavior of individuals with insomnia who observed a series of sleep-related and neutral words. Although the authors failed to provide evidence for a sleep-related attentional bias, this seminal study was the first to provide a timeline of attention allocation in insomnia. Expanding on words as stimuli, Beattie and colleagues¹² compared normal sleepers and individuals displaying insomnia symptoms in their gaze behavior whilst observing sleep-related items in the bedroom. The authors demonstrated that individuals presenting insomnia symptoms display an attentional bias towards beds in that they show a greater number, and longer duration of, fixations observing beds when compared to normal-sleepers.

The experience of tiredness is a commonly reported symptom amongst individuals with insomnia.¹⁷ Self-reports show that individuals with insomnia attend to bodily sensations, on waking and throughout the day, for signs of physical impairment including tiredness and fatigue (i.e. sore and heavy eyes) which may occur as a result of a poor night's sleep.^{18,19} Considering the prominence of the face in projecting tiredness cues to perceivers²⁰⁻²³, Akram and colleagues¹³ used eye-tracking to examine how individuals with insomnia observe faces in relation to tiredness. When asked to explore and examine their own and other people's faces, the authors determined that people with insomnia were quicker to direct their initial attention to, and maintain overall attention towards areas of the face associated with tiredness whilst viewing their own and other people's faces. These findings suggest that insomnia is characterised by a propensity to monitor faces for cues associated with tiredness. However, as neutral facial stimuli were presented and no facial manipulations portraying an increased perception of tiredness were used in this study, the findings are limited to suggestive evidence. That said, by using sleep-related facial stimuli depicting tiredness, this effect may theoretically be more profound.

As such, the present study used an eye-tracking paradigm to examine whether individuals with insomnia present an attentional bias for sleep-related facial stimuli depicting tiredness when compared to normal-sleepers. Specifically, this exploratory study aimed to determine whether: (i) compared to normal-sleepers, individuals with insomnia were quicker to orient and maintain overall

attention for faces depicting a tired facial expression (regardless of interest-region) relative to neutral faces; and (ii), the presence of an attentional bias for tired faces in insomnia was characterised by greater attention for the eye-region, relative to the nose and mouth regions.

Method

Participants

Participants were recruited from the general population using posters around Sheffield Hallam University, and social media. Participants completed a diagnostic screening questionnaire to determine eligibility to take part and group allocation – insomnia or normal-sleeper (see ‘Measures and materials’ for details). The sample consisted of 20 individuals with insomnia (mean age = 25.45 years, SD = 7.82 years; 85% female), and 20 normal-sleepers (mean age = 22.78 years, SD = 4.32 years; 74% female). The average duration of insomnia within the insomnia group was 38.33 months (SD = 60.68), ranging from 4 to 252 months. All participants had normal or corrected-to-normal vision.

Measures and materials

Screening questionnaire for eligibility and group allocation

A screening questionnaire determined eligibility and insomnia status. Individuals who reported symptoms of a sleep/wake disorder other than insomnia, an existing psychiatric illness, a central nervous system disorder, an ocular disorder, use of medication that may affect sleep, prior head injury or current shift-work were ineligible to participate. Participants with insomnia met DSM-5 criteria for insomnia disorder.²⁴ Specifically, individuals with insomnia reported dissatisfaction with sleep characterized by either a difficulty initiating or maintaining sleep or early morning awakenings. The insomnia had to be present for three or more nights per week, for at least three months, and cause significant daytime impairment. Finally, these conditions had to be met despite adequate opportunity to sleep. It was a requirement that normal-sleepers reported no problems with sleep and no history of any sleep-disorder. Of note, the SLEEP-50 questionnaire²⁵ was used to ensure the absence of a sleep/wake disorder other than insomnia (e.g. sleep apnea, narcolepsy, restless legs/periodic limb movement disorder, circadian rhythm disorder, sleep walking, nightmares).

Measures

The Insomnia Severity Index²⁶ (ISI) was used to assess symptom severity. The ISI consists of 7 items examining the severity of insomnia symptoms over the past two weeks including difficulty initiating and maintaining sleep, and awakening too early. Items are scored on a 5-point likert scale, with total scores ranging from 0–28. Higher scores represent greater insomnia severity. Assessment of internal consistency yielded a Cronbach’s alpha of .90. Symptoms of anxiety and depression were assessed using The Hospital Anxiety and Depression Scale²⁷ (HADS), consisting of 14 items (seven for both anxiety and depression) scored between 0-3, with a maximum score of 21 on both subscales. Higher scores on each subscale represent greater anxiety and depression. Both subscales demonstrated good internal consistency (Cronbach’s α = .84 for anxiety, and .84 for depression). The Stanford Sleepiness Scale²⁸ (SSS) was administered to assess participants’ state feeling of sleepiness. The measure consists of a 7 item likert scale ranging from 1 (feeling active, vital, alert, or wide awake) to 7 (no longer fighting sleep, sleep onset soon, having dreamlike thoughts). Higher scores are indicative of greater state sleepiness.

Facial stimuli

A subset of 12 tired-neutral face-pairs (50% female) previously developed by our group²³ were used for the present study. Specifically, facial photographs displaying a neutral expression were taken from the Karolinska Directed Emotional Faces database.²⁹ Subsequently, the hair and neckline was cropped from each neutral image, leaving a series of oval shaped neutral facial images. To create the corresponding threatening face pairs, which depicted a tired facial expression, each neutral face was subject to standardized manipulations of: increased pretarsal skin show; upper eyelid depression; dark circles under eyes; and drooped corners of the mouth (see 23 for details). These specific manipulations were used as they have previously been associated with an increased perception of tiredness.²⁰⁻²³ This resulted in a series of twelve face pairs comprised of a sleep-related (i.e. tired appearing) and neutral facial expression made by the same person (see Figure 1). In total, 24 face-pairs were presented to participants during the experimental task, which each of the 12 pairs being displayed four times.

INSERT FIGURE 1 HERE

Procedure

All participants provided written informed consent prior to participation. Ethical approval was granted by the Sheffield Hallam University Research Ethics committee. The experiment was conducted in a quiet laboratory room in the department. Eye movements were recorded using a Tobii TX300 desktop eye-tracker with an in-built 21.5" screen on which the stimuli were presented. First, a six-point calibration task was completed to confirm $< 1^\circ$ visual angle of recorded eye movements. Participants attended to the screen, and were required to fixate upon a dot that appeared on the center of the screen. Subsequently, a series of fixation dots successively appeared, and participants were required to direct their gaze and fixate upon each dot until the task was over. Upon successful calibration, the experimental task began. For each trial, participants were presented with a threat-neutral face pair for 4000msec and were asked to observe the faces naturally. Prior to each trial, a fixation cross was displayed in the center of the screen to ensure standardization of starting gaze location. The order of presentation was randomized and forty-eight trials were completed in total, with each the twelve face pairs being presented four-times counterbalanced. After completing the task, participants were thanked, debriefed and provided with a high street voucher in return for their participation. .

Statistical Analyses

Interest-regions

To examine how participants observed the presented tired-neutral face pairs, three interest-regions for each face were pre-determined and analyzed for first fixation onset, first fixation duration, total fixation duration, and total gaze duration in milliseconds (msec): the eyes; the nose; and mouth (See Figure 2 for an example of interest-regions used for analyses). The eye-region accounted for pretarsal skin show, upper eyelid depression, dark circles under the eyes, and wrinkles/ lines around the eye-region including the skin above the nose (i.e. glabella) and lower forehead, and crows-feet as these features have previously been associated with tiredness.^{20-23, 30}

For each interest-region: first fixation onset was defined as the amount of time elapsed (in msec) before the first fixation landed within the interest-region; first fixation duration was defined as the

time (in msec) between the start of the first fixation which landed within the interest-region until this fixation oriented elsewhere; total fixation duration was defined as the total duration of all fixations made within each interest-region (in msec); and total gaze duration was defined as the total summation of the fixations' duration (in msec) that landed within the interest-region. These were extracted for analysis using the 'Tobii Studio' computer software. SPSS was used to perform formal statistical analyses of the differences in mean gaze-durations between and within participant groups.

INSERT FIGURE 2 HERE

Analyses

First, to validate group profiles and confirm correct allocation, a series of group comparisons (independent samples *t*-tests) were made on the questionnaire measures. Following, a series of 2 (group: insomnia vs. normal-sleepers) x 2 (face: tired vs. neutral) x 3 (interest-region: eye-region vs. nose-region vs. region) mixed measures ANOVA analyses were employed, with first fixation onset, first fixation duration, total fixation duration, and total gaze-duration as dependent variables. This was conducted to assess the main effects of group, face, and interest-region. The group x face, group x interest-region, face x interest-region, and group x face x interest-region interactions were also assessed. Tests for pairwise comparisons were also conducted. Significance was considered at the $P < .05$ level.

Results

Mean scores for first fixation onset, first fixation duration, total fixation duration, and total gaze duration for each group are presented in Table 1. The insomnia group scored significantly higher (14.75 ± 4.39) on the ISI compared to normal-sleepers (4.20 ± 3.31), confirming group profiles ($t(38) = -8.47, P = .001$). Moreover, the insomnia group also scored higher on anxiety (10.10 ± 4.01 ; $t(38) = -3.86, P = .001$) and depression (5.65 ± 4.06 ; $t(38) = -3.62, P = .001$) relative to the normal sleepers group (anxiety = 5.75 ± 3.04 ; depression = 2.00 ± 1.94). In line with Woods and colleagues,¹¹ this was not controlled for after considering the bidirectional relationship of anxiety and depression with insomnia.³¹ Rather, this was taken as a characteristic of the insomnia disorder. The only difference which was not significant between individuals with insomnia (2.45 ± 1.54) and normal-sleepers (2.95 ± 1.58) was found in the SSS ($t(38) = -1.15, P = .26$).

INSERT TABLE 1 HERE

First Fixation Onset

The results demonstrated no significant effects of group ($F(1,38) = 1.12, P = .30$), face ($F(1,38) = 1.47, P = .23$) or interest-region ($F(2,76) = .45, P = .66$), or group x interest region ($F(2,114) = 1.16, P = .32$), group x face ($F(1,76) = .25, P = .25$) or group x face x interest region ($F(2,114) = .58, P = .94$) interactions concerning first fixation onset.

First Fixation Duration

The results revealed a significant main effect of interest-region ($F(2,76) = 28.22, P = .001$) on first fixation duration. Pairwise comparisons confirmed that regardless of the face presented (tired or neutral), all participants initially fixated on the eye-region (107 ± 6 msec) for longer than the nose

(71±7msec) and the mouth (52±7msec) regions. However, there were no differences in how participants fixated on the nose and mouth. No significant effects of group ($F(1,38)=2.34, P=.14$) or face ($F(1,38)=1.08, P=.31$), or group x face ($F(1,76)=1.08, P=.31$), face x interest-region ($F(2,76)=1.46, P=.24$), or group x face x interest-region ($F(2,114)=1.77, P=.18$) interactions were observed.

Total Fixation Duration

The results revealed a significant main effect of interest-region ($F(2,76)=62.78, P=.001$) on total fixation duration. Pairwise comparisons confirmed that regardless of the face presented (tired or neutral), all participants fixated on the eye-region (577±54msec) for longer than the nose (157±20msec) and the mouth (115±18msec) regions. However, there were no differences in how participants fixated on the nose and mouth. A main effect of face was also determined ($F(1,38)=5.76, P=.02$), suggesting that regardless of group or interest-region, all participants fixated on the tired faces for longer (307±26) than the neutral faces (258±23msec). However, no main effect of group was observed ($F(1,38)=2.05, P=.16$).

A significant face x region interaction ($F(2,40)=6.18, P=.02$) was demonstrated, indicating that regardless of group, all participants spent more time fixating on the eye-region of the tired face (640±65) compared to the neutral face (513±53msec). Moreover, a significant group x face interaction ($F(1,76)=4.07, P=.05$) indicated that, irrespective of the interest region, participants with insomnia spent more time fixating on the tired faces (360±37msec) than the neutral faces (271±33msec) when compared with normal-sleepers (tired:254±37; neutral:247±33msec). Finally, a significant group x face x interest-region interaction ($F(2,114)=3.51, P=.03$) demonstrated that individuals with insomnia spent more time fixating on the eye-region of the tired faces (739±93msec) for longer than the eye-region of the neutral faces (512±75msec) when compared with normal-sleepers (tired eye-region:542±93; neutral:515±75msec). This outcome suggests that individuals with insomnia display an attentional bias towards tired faces, and more specifically the eye-region compared to normal sleepers.

Total Gaze Duration

The results revealed a significant main effect of interest-region ($F(2,76)=68.51, P=.001$) on total gaze duration. Pairwise comparisons confirmed that regardless of the face presented (tired or neutral), all participants observed the eye-region (624±56msec) for longer than the nose (162±20msec) and the mouth (119±18msec) regions. However, there were no differences in how participants observed the nose and mouth. A main effect of face was also determined ($F(1,38)=5.77, P=.02$), suggesting that regardless of group or interest-region, all participants observed the tired faces for longer (327±26msec) than the neutral faces (276±24msec). However, no main effect of group was observed (stat).

A significant group x face interaction ($F(1,76)=4.15, P=.05$) indicated that, irrespective of the interest region, participants with insomnia spent more time observing the tired faces (380±38msec) than the neutral faces (285±34msec) when compared with normal-sleepers (tired:275±38; neutral:267±34msec). Further, a significant group x face x interest-region interaction ($F(2,114)=3.57, P=.03$) demonstrated that individuals with insomnia spent more time observing the eye-region of the tired faces (788±97msec) for longer than the eye-region of the neutral faces

(547±78) when compared with normal-sleepers (tired eye-region:594±97; neutral:568±78msec). Again, these results suggest that individuals with insomnia display an attentional bias towards tired faces, and more specifically the eye-region compared to normal sleepers. No region x group interaction was observed ($F(2,114)=.12, P=.87$).

Discussion

The present study examined: (i) whether compared to normal-sleepers, individuals with insomnia were quicker to orient and maintain overall attention for faces depicting a tired facial expression (regardless of interest-region) relative to neutral faces; and (ii), whether the presence of an attentional bias for tired faces in insomnia was characterised by heightened attention for the eye-region, relative to the nose and mouth regions. First, the current findings demonstrated that individuals with insomnia spent more time fixating on and observing tired, rather than neutral faces, when compared to normal-sleepers. Therefore, suggesting that a sleep-related attentional bias for faces depicting tiredness may be present amongst individuals with insomnia. Second, the current outcomes demonstrate that this potential bias for tired faces appears to be predominately focused on the eye-region.

Evidence highlights a significant role of the eye-region in projecting tiredness cues to perceivers²¹⁻²³, and prior research has demonstrated that individuals with insomnia show preferential attention for the eye-region of neutral faces¹³. From a cognitive perspective it is theorized that insomnia is partly maintained by selective attention, monitoring and interpretive biases for cues that indicate the presence of a poor night's sleep.^{1,2} Indeed, individuals with insomnia often report selectively attending to bodily sensations on waking and throughout the day for signs of impairment, which include tiredness (i.e. sore head, heavy eyes) as a result of a poor night's sleep.^{18-19, 32} Here, the current results expand on previous research¹³ by providing objective support for the notion that individuals with insomnia display a tendency to monitor faces, with a specific focus around the eye-region, for cues associated with tiredness (i.e. hanging eyelids, dark circles, wrinkles and lines around the eyes). Indeed, greater emphasis placed upon these cues upon awakening and during the day to confirm the nature of their sleep disturbance would certainly serve to fuel worry, arousal and distress as described in cognitive models of insomnia.^{1,2}

Whilst individuals with insomnia spent more time fixating on and observing tired faces, and more specifically the eye-region, no group differences concerning first fixation onset or first fixation duration were established. This finding is in line with prior eye-tracking research¹² evidencing that individuals presenting insomnia symptoms allocate greater attention (categorised by number of fixations) for sleep-related stimuli (i.e. beds) in natural visual scenes relative to normal-sleepers. Crucially, the authors found no group difference concerning the time delay to first fixate on beds in these scenes. Taken together, it appears that individuals with insomnia maintain visual attention towards sleep-related stimuli, in this case tired faces; however, they are not quicker in orienting attention towards such stimuli. Alternatively, a visual perception alteration may eventually occur amongst individuals with insomnia where the ability to accurately gauge facial expression, in this case tiredness, becomes impaired.²³ As a result, it may be proposed that visual attention for expressive faces may be prolonged, perhaps in an effort to make an accurate judgment.

Individuals with insomnia commonly interpret negative attributes relating to physical self-perception

(i.e. facial cues of tiredness, facial complexion cutaneous features)^{13,20,33,34}, and correcting the perception of such attributes (i.e. facial tiredness cues) may present novel treatment approaches. Indeed, providing feedback relating to a self-misperception of facial tiredness in this population has previously served to improve subsequent interpretations such that participants later interpreted themselves as appearing less tired.²⁰ Theoretically, the initiation of a more accurate self-perception could eliminate one maintaining factor of the disorder (i.e. the propensity to negatively interpret physical cues consistent with a poor night's sleep). That said, we need to consider that attention precedes interpretation.³⁵ Considering this, recent research has examined the efficacy of delivering attentional bias modification (ABM) immediately prior to bed as a treatment for individuals displaying poor sleep quality.^{36,37} These studies determined that poor-sleepers provided with ABM displayed improved subjective sleep quality, reduced pre-sleep arousal, and reduced sleep onset latency relative to poor-sleeping controls. In relation to the present study, individuals with insomnia demonstrated a sleep-related attentional bias for physical facial cues pertaining to tiredness, specifically showing difficulty in disengaging attention away from such cues. Therefore, it may be worthwhile for targeted attentional modification tasks to use sleep-related facial stimuli in an effort to reduce attention to this sleep-specific cue. However, as recently highlighted³⁵ research in this area is in its early stage, limited to a number of specific research groups. Considering the salience of tiredness in relation to insomnia, research in this area should be replicated refined before considering intervention.

Salient, often disorder-consistent or relevant faces are widely used to examine the presence of an attentional bias in many psychopathologies including anxiety and depression. For example, individuals with anxiety often show an attentional bias for faces which display the expression of anger^{35,36}, whereas individuals with depression often show a bias for faces depicting sadness.³⁷ As such, the current outcomes are novel in that they move the insomnia-attentional bias literature forward, bringing research in this area in line with other psychological disorders.

Several limitations of the current study should be noted. The current sample consisted primarily of female participants in the insomnia group. As such, the present findings may not be fully generalizable to males. However, it is relevant to note that women are more likely than men to be diagnosed with insomnia.³⁸ Moreover, whilst the facial stimuli depicting tiredness were based on established tiredness cues²⁰⁻²³, they were not naturally occurring. Considering this, facial stimuli based on photographs of individuals displaying experimentally induced tiredness through sleep deprivation may be more suitable. Finally, the sample size was small, although similar to previous eye-tracking studies which have examined the presence of an attentional bias in insomnia.¹¹⁻¹³ That said, future studies may wish to consider using a power analysis to determine an adequate sample size prior to data collection.

To summarize, the present study suggests that individuals with insomnia display an attentional bias for faces depicting a tired facial expression, with a particular focus on eye-region cues which portray tiredness. These findings contribute to our understanding of face perception in insomnia and provide tentative support for cognitive models of the disorder^{1,2}, highlighting that individuals with insomnia potentially monitor faces, with a specific focus around the eye-region, for cues associated with tiredness.

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